Acoustic Wave Propagation in Water Filled Buried Polyethylene Pipes

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Abstract

Axisymmetric acoustic modes propagating along buried water pipes have been investigated experimentally and by the method of finite elements. High precision dispersion relations are presented in this paper as a function of the geometry, the surrounding material and the elastic modulus of the buried pipe (figure 1).

The company Hinni AG is the leading manufacturer of hydrants in Switzerland. In 2005 Hinni AG introduced a monitoring system of the water distribution network which can detect water leaks, but not locate them. The procedure is based on hydrants which are equipped with hydrophones. Together with Hinni AG we are currently establishing a method to also locate the source of the leakage. The technique relies on the acoustic noise recorded at two hydrant sites. The time delay of the acoustic signals found by cross-correlation yields a length difference of the guiding pipe sections and thus pinpoints the leak. Details of this detection method can be found in refs. [1-3].

In order to locate the leak precisely a detailed knowledge of the noise propagation is essential. Dispersion and attenuation of the signal and scattering at joints, fittings and bends blur the correlation function and render the task of localization very difficult.
Water filled ductile iron pipes have been studied in the past (e.g. ref. [4]). Iron pipes exhibit insignificant dispersion and minor radiation losses at low and moderate frequencies, which are commonly used in the correlators. However, water filled polyethylene pipes with small elastic modulus display a more complex acoustic behavior.

At very low frequencies the fundamental axisymmetric acoustic mode of the water cylinder is nearly a plane wave. This mode is the dominant component of the noise signal propagating along the pipe. At moderate frequencies the acoustic pressure is small in the center of the water column and builds up close to the elastic layer, inside and outside the pipe (fig. 2). Attenuation at moderate frequencies is not substantial because the wave is propagating along the pipe with hardly any radiation losses to the surrounding. At still higher frequencies an additional mode emerges in the water cylinder, driven by the wave in the elastic pipe layer.

Based on our simulations and measurements we discuss the potentials of fabricating a leak detection system by means of hydrophones. The hydrophones listen to the leak noise in the water stream. The water cylinder has been identified as the primary propagation channel for leak noise at low frequencies. Therefore hydrophones can detect low frequency signals from far away, in

contrast to accelerometers mounted on the stem of the hydrants.

Keywords: Buried polyethylene water pipes, leak detection, axisymmetric acoustic mode, acoustic phase velocity, finite element modelling (FEM).

Reference

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Figures used in the abstract

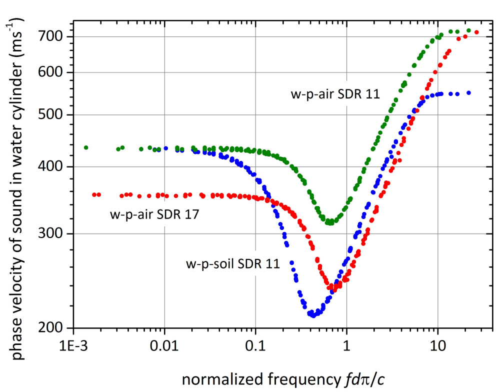

Figure 1: Calculated phase velocities of the fundamental acoustic mode in water filled pipes as a function of frequency and surrounding. The frequency is normalized by multiplication with the inner circumference and division by the sound velocity of water. Data of various pipe diameters display universal curves. SDR 11 and 17 are standard numbers for the ratios of the outer diameter to the wall thickness of the pipe.

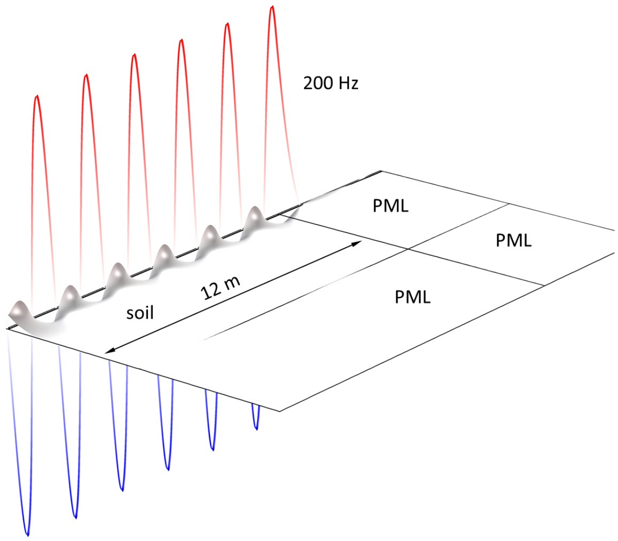

Figure 2: Computed acoustic pressures in a strait water-pipe-soil section. The harmonic excitation of the water cylinder at 200 Hz is implemented as a normal acceleration boundary condition on the far left of the pipe. The acoustic pressure builds up at the pipe wall. A large-amplitude wave (red and blue oscillations) propagates in water, a small-amplitude wave propagates in the soil adherent to the pipe. The simulation domains are terminated by perfectly matched layers (PML).